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UNITED STATES BUREAU OF MINES
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INFORMATION CIRCULAR

EXPLOSIONS IN KENTUCKY COAL MINES, JANUARY 1, 1884 - JUNE 30, 1933

BY

J. F. DAVIES AND H. B. HUMPHREY

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EXPLOSIONS IN KENTUCKY COAL MINES, JANUARY 1, 1884 - JUNE 30, 1933[1]

By J. F. Davies[2] and H. B. Humphrey[3]

PURPOSE OF THIS REPORT

Prevention of coal-mine explosions depends largely upon thorough knowledge of the causes that initiate explosions. A review of coal-mine explosions in one geographical area when supplemented by nationwide data of similar nature, should serve as a guide for the adoption of measures for explosion prevention. Explosions in bituminous-coal mines of the United States during the 10 years ended December 31, 1932, ranked third in the causes of fatal accidents and constituted 16.1 percent of all fatal accidents in bituminous mines.

Kentucky now ranks fourth in coal output in the coal-producing States of this country; a study of the coal-mine explosions in this State will be of definite interest locally among coal-mining people, as well as to those in the coal-mining industry who are concerned in preventing coal-mine explosions. This circular reviews gas and dust explosions in Kentucky coal mines to show their hazards, to point out the influence of certain factors in causing explosions, and to indicate the effectiveness of preventive measures.

The annual reports of the Kentucky Department of Mines and data published by the United States Bureau of Mines were used in compiling the tables of explosions and fatalities. These were supplemented by information furnished by individuals and operators connected with the industry in the State in past years. Through the cooperation of J. F. Daniel, chief of the Kentucky Department of Mines, several doubtful cases were clarified. So far as records are obtainable the history is comparatively complete, but it must be recognized that for various reasons some occurrences and fatalities

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were not reported or the records thereon were lost. Figures used in compiling some of the tables were furnished by W. W. Adams, chief statistician, Demographical Division, United States Bureau of Mines.

GROWTH IN PRODUCTION

Probably the first record regarding a coal deposit in the United States is that made in 1679 by Father Hennepin, a French Jesuit missionary, of a "cole mine" seen on the Illinois River near Ottowa, Ill., in what was then Kentucky. The first white settler to discover and use Kentucky coal was Dr. Thomas Walker. While on a survey journey on April 13, 1750, he found at a point within 2 miles of Cumberland Gap in what is now Bell County "blocks of very good coal on the surface". His diary records many other coal occurrences as he traversed the region. In 1790 the first iron furnace was erected near Cwingsville, using charcoal for smelting but coal for refining the metal. Considerable amounts were used locally in the older towns, such as Lexington and Frankfort, after 1800.

In 1830 W. D. McLean opened what became known as the "McLean drift bank" on the Green River; this is regarded as the first commercial operation in the western coal field. In 1854 the Kentucky Geological Survey was established to gather and disseminate information on the extensive and important mineral deposits of the State. Coal production grew from 25,000 tons in 1840 to 100,000 tons in 1845 and 150,000 in 1850. Numerous wagon and barge mines were being worked along the Big Sandy, Licking, Kuntucky, Cumberland, Green, and Tradewater Rivers. In the western field, Henderson County, a number of small surface mines were in operation, and to the south in Muhlenberg County the Med River mine, opened in 1830, was actively producing. During and immediately after the Civil War production was greatly depressed, less than 170,000 tons being mined in 1870. By 1880 the production had reached a million tons annually, and it increased to over 2-1/2 million tons in 1890. Added transportation facilities helped to increase the figure to 35 million tons per year by 1920, and the greatest annual production was 69 million tons in 1927. In 1932, 35,610,000 tons production was reported.

HISTORY OF EXPLOSIONS

In the early years while the mines were preponderantly of the drift type and at no great distance from the surface the presence of explosive gas was noticed in only a few instances. The earliest ignition of which mention was found occurred in Garrard mine in Clay County in 1877; after the mine had been worked for some years gas appeared suddenly from a roof fissure, and in the resulting ignition one man and possibly others were seriously burned. A similar ignition occurred in the same mine in 1881, and there was another in the Mercer mine in Muhlenberg County about 1880. In 1885 gas was known to have appeared in only 6 mines, but the chief of the State Department of Mines issued repeated warnings that the hazard would increase as the workings were extended.

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Case	Date	County	Mine, type	Approximate daily tonnage	Average No. employed	No. in mine	Explosion: Type	Explosion: Extent	Explosion: Probably limited by	Cause	Source of ignition	Other factors	Possible means of prevention	Killed	Injured	Recovered	Uninjured (Fatal)
1	1887 Oct. 7	Hopkins.	Shaft, gassy.	100	20	20	Gas, dust.	Strong.	Expansion.	Incomplete ventilation, gas under 5 percent.	"Windy" shot.	Burned men.	Safer blasting, improve ventilation.	3		10	3
2	1888 Dec. 8	do.	do.	100	20	3	do.	Local.	Weak start.	Probably "windy" shot and 3 kegs of black blasting powder.	Blasting.	Explosion.	do.	3		0	3
3	1894 - -	do.	do.	200	50	-	Dust.	do.	Expansion.	Overcharged shot on solid.	Blown-out shot.	Black blasting powder.	Cut coal, safe use of explosives.	0	1	0	0
4	1895 Jan. 22	Union.	Slope, nongassy.	25	5	5	do.	Strong.	do.	do.	do.	Three kegs of black blasting powder.	do.	5	0	0	5
5	1897 Apr. 16	Hopkins.	Shaft, gassy.	200	50	3	Gas, dust.	Violent.	Swept mine.	do.	do.	Shot firers	Cut coal, safer blasting, and ventilation.	2	1	0	2
6	1899 Oct. 4	Union.	Slope, gassy.	400	140	100	Gas.	Local	No force.	Entry idle a week account of feeders.	Open light.	Entered against orders.	Supervision.	0	2	0	0
7	1902 Feb. 15	Muhlenberg.	Shaft, gassy.	1,000	200	200	Gas, dust.	do.	do.	Poor ventilation, solid shot.	Blasting.	Black blasting powder.	Ventilation, cut coal, safer blasting.	0	3	16	0
8	1903 Dec.	Whitley.	Drift, nongassy.	-	-	2	Dust.	Strong.	Expansion.	-	Blown-out shot.	2 miners.	Cut coal, safer blasting, control dust.	2	-	-	2
9	1904 Apr. 20	do.	do.	50	11	2	do.	Violent.	To outside.	4 shots on solid, black blasting powder and coal dust.	do.	3 on outside	Cut coal, safer blasting, water.	5	0	0	-
10	1904 Dec. 2	do.	do.	150	30	10	do.	Strong.	Expansion	Lack of ventilation, shot on solid.	do.	Overloaded.	Cut coal, ventilation, safer blasting.	1	6	3	6
11	1905 Mar. 3	do.	do.	100?	20?	?	do.	Violent.	To outside.	Solid shooting.	do.	Black blasting powder.	Cut coal, safer blasting.	0	2	-	-
12	1905 Dec. 29	do.	do.	200	50	3	do.	do.	do.	Solid shooting, "windy" shot.	Blasting.	2 shot firers, 1 hurt outside.	do.	2	1	1	2
13	1906 Mar. 10	do.	do.	100?	-	2	do.	Local.	Expansion.	do.	do.	Dusty.	Cut coal, safer blasting, water.	2	-	-	-
14	1906 July 12	Muhlenberg.	Slope, gassy.	500	70	60	Gas.	Strong.	do.	Unventilated room, idle.	Open light.	Repair man loaned in.	Ventilation and inspection.	0	1	-	-
15	1906 Oct. 2	do.	do.	500	70	60	do.	Ignition.	Small volume.	Unventilated entry, stopped.	do.	"Marked out"	do.	1	1	0	3
16	1907 Jan. 21	do.	Shaft, gassy.	300	50	-	do.	Local.	Expansion.	Poor ventilation and fire.	do.	Another Feb. 8.	do.	0	0	0	-
17	1907 Nov. 21	do.	do.	-	100	90	Dust.	do.	do.	2 overcharged shots, both blew out.	Blasting.	Dusty.	Safer blasting.	1	4	-	-
18	1907 Dec. 7	Bell.	Drift, nongassy.	250	46	8	do.	do.	do.	9 shots on solid at same time.	do.	Dusty mine, coal dust stemming.	Cut coal, ventilation, safer blasting, water.	0	6	0	1
19	1908 Feb. 4	Union.	Shaft, gassy.	250	50	30	do.	do.	do.	1 overcharged solid shot.	"Windy" shot.	Possibly gas also.	Cut coal, safer blasting, supervision.	3	4	0	-
20	1908 Feb. 10	Muhlenberg.	do.	75	20	13	do.	Strong.	do.	3 overcharged solid shots.	Blown-out shot.	do.	Cut coal, safer blasting, water.	9	1	0	-
21	1908 Oct. 9	Bell.	Drift, nongassy.	30	10	8	do.	Local.	do.	Heavy shots on solid.	do.	Local.	Cut coal, safer blasting.	0	8	-	-
22	1908 - -	Whitley.	do.	250	50	3	do.	do.	do.	Blew out steppings, 3 shots fired.	do.	-	do.	0	0	3	12
23	1909 Dec. 11	Webster.	Shaft, gassy.	650	130	7	Gas.	Violent	Expansion, water.	Gas trapped in abandoned workings 120' below water.	Open fire or light.	Water came to surface	Boreholes to release gas.	7	0	0	7
24	1910 Feb. 1	Muhlenberg.	do.	400	80	80	Gas, dust.	do.	Expansion.	Unventilated idle rooms.	Open light.	Spread by kegs of black blasting powder.	Ventilation, safer storage of "powder", inspection, water.	36	6	0	-
25	1910 Feb. 8	Whitley.	Drift, gassy.	400	150	6	Dust.	Strong.	do.	Overcharged solid shot of black powder.	Blown-out shot.	Night shift.	Cut coal, safer blasting, water.	6	0	0	-
26	1910 Nov. 25	Webster.	Shaft, gassy.	100	20	10	do.	Violent.	Wrecked mine.	do.	"Windy" shot.	Kegs of black blasting powder.	Cut coal, safer blasting, and storage.	10	0	0	30
27	1911 Jan. 6	Lee.	Drift, nongassy.	75	20	20	do.	Local.	Expansion.	Overcharged solid shots.	Blown-out shot.	Black blasting powder.	Cut coal, safer blasting.	0	17	0	-
28	1911 Jan. 21	Webster.	Slope, nongassy.	650	125	25	do.	do.	do.	4 overcharged shots, left 1 in open.	do.	"Powder" smoke.	do.	0	0	0	-
29	1911 Dec. 8	Muhlenberg.	Shaft, gassy.	75	15	1	do.	do.	Little force.	11 solid shots near together.	do.	"Powder" smoke.	do.	1	0	0	1
30	1912 Jan. 17	do.	do.	750	150	5	do.	Strong.	Expansion.	2 overcharged shots through before entering.	do.	Aided by kegs of black blasting powder.	Cut coal, permissible explosives.	5	0	0	-
31	1912 Apr. 21	Hopkins.	do.	180	40	5	Gas.	Violent.	Wrecked mine.	Fan shut down Sunday, not started before entering.	Open light.	Possibly also dust.	Start fan before entering, closed lights, inspection.	5	0	0	10
32	1914 Jan. 1	Webster.	do.	500	100	2	Dust.	Strong.	Expansion.	Delayed solid shot.	Blown-out shot.	Keg black blasting powder.	Cut coal, permissible blasting, rock-dust.	1	1	0	1
33	1916 May -	do.	do.	500	100	-	do.	do.	do.	-	do.	-	do.	0	0	0	0
34	1917 Aug. 4	do.	do.	1,500	300	153	Gas, dust.	Violent.	Expansion and inert dust.	Car standing under curtain, furnace ventilation.	Open light.	Inadequate inspection.	Inspection, closed lights, rock-dust.	62	18	43	-
35	1917 Dec. 10	McCreary.[2]	Drift, nongassy.	300	75	2	Dust.	do.	Wrecked fan.	Solid shooting, 2 shot firers.	Blown-out shot.	-	Cut coal, permissible blasting, rock-dust.	2	0	0	-
36	1917 Dec. 30	Letcher.	do.	300	75	4	do.	Strong.	Expansion.	6 solid shots together, black powder.	"Windy" shots.	Coal dust stemming.	Permissible blasting, supervision, rock-dust.	0	4	0	6
37	1918 July 27	Union.	Slope, gassy.	600	150	1	Gas.	Local.	do.	Inadequate ventilation, pump in idle section.	Open light.	Pumper went in before fire-boss.	Ventilation, inspection, closed lights.	1	0	0	1
38	1919 Feb. -	-	-	-	-	-	Dust.	-	-	-	No report.	-	-	2	-	-	-
39	1919 Dec. -	-	-	-	-	-	do.	-	-	-	do.	-	-	1	-	-	3
40	1920 Feb. 23	McCreary.	Drift, gassy.	500	100	90	Gas.	Local ignition.	Small volume.	Place marked off on bulletin board, not noted by miner.	Open light.	Trackman	Closed lights, supervision.	1	0	0	-
41	1920 Apr. 13	Harlan	do.	3,500	600	500	do.	do.	do.	Inadequate ventilation, place marked out.	do.	Foreman and coal loader went in Safety Lamp, not lit.	Ventilation, closed lights.	1	0	0	-

1 No explosions, 1884-1886.
2 McCreary County established in 1912 from Whitley County.

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TABLE 1.--Gas and dust explosions in Kentucky coal mines, January 1, 1884-June 30, 1933 (Continued)

Case	Date	County	Mine, type	Approximate daily tonnage	Average No. employed	No. in mine	Explosion: Type	Explosion: Extent	Explosion: Probably limited by	Cause	Source of ignition	Other factors	Possible means of prevention	Killed	Injured	Escaped from mine unharmed	Later lost (Killed)
42	1920 Dec. 20	Letcher.	Drift, nongassy.	100	20	2	Dust.	Local.	Expansion.	Solid shooting.	"Windy" shot.	-	Safer blasting, cut coal, rock-dust.	2	0	0	4
43	1921 Sept. 12	Muhlenberg.	Shaft, gassy	500	110	10	Gas.	do.	do.	Fireboss moving gas by brushing.	Open light.	Had mixed lights.	Ventilation, closed lights.	1	0	0	-
44	1921 Oct. 17	Pike.	Drift, nongassy.	100	30	10	Dust.	do.	do.	Several solid shots, black blasting powder.	Blown-out shot.	Coal-dust tamping.	Cut coal, permissible blasting.	3	1	0	4
45	1922 Jan. 30	Bell.	do.	150	37	8	do.	To outside.	Weakness.	Dust raised by 5 other solid shots.	do.	Furnace was out.	Cut coal, permissible blasting, ventilation, supervision.	6	2	0	-
46	1922 Feb. 7	Pike.	do.	275	44	11	do.	do.	do.	Dust raised by 5 other "windy" shots.	do.	Overcharged, on solid.	do.	9	2	0	-
47	1922 Mar. 23	do.	Drift, gassy.	210	50	-	Gas.	Local	No force.	At room face.	Open light(?).	Burned.	Inspection and closed lights.	1	0	-	-
48	1922 Apr. 3	do.	Drift, nongassy.	100	30	3	Dust.	do.	Weakness.	Dust raised by 8 solid shots.	Blown-out shot.	Had been ordered cut	Cut coal, permissible blasting, supervision.	2	0	1	18
49	1923 Feb. 23	Muhlenberg.	Shaft, gassy.	1,600	350	75	Gas.	do.	Expansion.	Opening sealed area.	Open light.	Lack proper ventilation and inspection.	Ventilation, inspection, closed lights.	1	7	0	-
50	1923 Mar. 29	Union.	Slope, gassy.	900	125	1	do.	do.	No force.	Went over inspector's danger board.	do.	Burned.	Closed lights and supervision.	1	0	0	-
51	1923 June -	-	-	-	-	-	do.	-	-	-	do.	-	Ventilation and closed lights.	1	-	-	-
52	1923 Dec. 1	McCreary.	Drift, gassy.	1,200	300	1	Dust.	Local.	Weak start.	Solid shots, black blasting powder.	Blown-out shot.	Coal-dust stemming.	Cut coal, permissible blasting.	1	0	0	-
53	1923 Dec. 7	Perry.	Drift, nongassy.	150	45	16	Gas, dust.	Strong.	Expansion.	3 solid shots, 1 "windy", 1 blown-out.	do.	-	Cut coal, permissible blasting, rock-dust.	9	4	3	13
54	1924 Oct. 22	Hopkins.	Shaft, nongassy.	1,000	200	18	Dust.	Violent.	Expansion only.	8 solid shots in room and crosscut.	"Windy" shot.	2 kegs black blasting powder.	do.	3	0	15	3
55	1925 Jan. 15	Webster.	Slope, nongassy.	500	85	7	do.	Strong.	Damp dirt on slope entries.	Machine shot on solid this day, overcharged.	Blown-out shot.	Black blasting powder, coal dust.	Cut coal, permissible blasting, rock-dust, water.	6	0	1	-
56	1925 May 3	Hopkins.	Shaft, gassy.	500	45	7	Gas.	Local.	No force.	Repair crew.	Open light.	Burned.	Ventilation, inspection, closed lights.	2	3	2	-
57	1925 June 8	Union.	do.	1,000	180	180	Gas, dust.	do.	Rock-dust.	Fireboss "passed up" rooms.	do.	Confined to section not rock-dusted.	do.	17	0	0	-
58	1925 Sept. 1	Muhlenberg.	do.	300	60	50	Gas.	do.	No force.	Room fell in, gas accumulated.	do.	Climbed on fall.	Closed lights, inspection.	2	1	4	-
59	1925 Nov. 18	Hopkins.	Shaft, nongassy.	200	30	7	Dust.	Strong.	Expansion.	Black powder in keg ignited by open light.	do.	2 in safety chamber.	Closed lights, permissible blasting, cut coal.	5	0	2	32
60	1926 Feb. 16	Muhlenberg.	Shaft, gassy.	500	150	100	Gas, dust.	Local.	Inert dust, weak start.	Dependent shot on solid, black blasting powder.	Blown-out shot.	3 killed by explosion, 5 rescuers by CO.	Cut coal, permissible blasting.	8	0	0	-
61	1926 Apr. 21	Webster.	do.	1,500	215	2	Gas.	Local.	No force.	Fireboss ran into gas.	Open light.	-	Closed lights.	1	0	1	9
62	1927 Jan. 31	Hopkins.	Slope, nongassy.	100	40	10	do.	do.	Small force and wetness.	First appearance of gas, fan idle over night.	Electric arc.	When power put on blower fan.	Ventilation and inspection before entrance of men.	4	0	6	-
63	1927 Mar. 14	Bell.	Drift, gassy.	1,100	250	1	do.	do.	Small force.	Unventilated face, fireboss ran mining machine.	Open light.	Section foreman.	Ventilation, inspection, closed lights.	1	0	0	-
64	1927 Aug. 3	Webster.	Shaft, gassy.	900	215	45	Gas, dust.	do.	Rock-dust.	Gas liberated by shots, passed over mining machine.	Electric arc.	Open-type machine.	Ventilation, inspection, rock-dust, permissible equipment.	15	0	15	-
65	1927 Oct. 29	McCreary.	Drift, gassy.	900	240	200	Gas.	do.	No force.	"Fanning" out gas, passed over lights.	Open light.	Burned.	Ventilation, closed lights.	1	0	1	21
66	1928 May 22	Harlan.	Drift, nongassy.	3,300	650	68	Dust.	Strong.	Expansion.	Adobe shot on large rock.	Blasting.	40 percent dynamite, 1 killed in recovery work.	Permissible blasting, rock-dust, water on machine.	8	0	8	-
67	1928 Nov. 27	Martin.	Drift, gassy.	1,100	130	3	Gas.	Local.	do.	Mine idle since July.	Open light.	3 officials.	Closed lights, supervision.	3	0	0	-
68	1928 Dec. 18	Muhlenberg.	Shaft, gassy.	1,000	125	11	Gas, dust.	do.	do.	Caving rooms liberated gas.	do.	Opened flame safety lamp.	Ventilation, inspection, closed lights, rock-dust.	6	0	5	17
69	1929 Jan. 21	Hopkins.	Slope, nongassy.	200	50	2	Dust.	Wrecked mine.	Small mine.	Incompetent supervision.	Blown-out shot.	Black blasting powder.	Supervision, cut coal, permissible blasting.	2	0	0	2
70	1930 Mar. 29	Bell.	Drift, gassy.	1,100	220	200	Gas, dust.	Strong.	Wet section, expansion.	Partly sealed area.	Open light.	Entered unventilated area with open light.	Ventilation or sealing, inspection, closed lights, rock-dust.	16	0	0	16
71	1931 Oct. 29	Harlan.	do.	4,500	500	500	Gas.	Local	Wet area, weak ignition.	Machine cut feeder, lack of ventilation.	Smoking.	Killed by burns.	Ventilation, inspection, prohibition of smoking.	3	1	6	3
72	1932 Dec. 9	do.	Drift, nongassy.	250	45	37	Dust.	Strong.	Expansion.	2 blown-out solid shots, black blasting powder.	Blown-out shot.	Gobbed fines.	Permissible blasting, cut coal, rock-dust, supervision.	23	0	14	23
73	1933 May 15	McCreary.	Drift, gassy.	600	125	9	Gas.	Local.	Inert dust.	Inadequate inspection and ventilation.	Open light.	Engineer party.	Ventilation, inspection, closed lights.	3	0	0	3
		Total		41,195	7,988	3,127								344	123	159	344

Note: In the years which are omitted no explosions or fatal ignitions are known to have occurred.

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Table 1 lists 73 explosions in Kentucky coal mines of which record was available from 1884 to June 30, 1933, inclusive. Except for a few cases where full information was lacking the essential facts about the explosions are given; these explosions include all in which fatalities occurred or in which there was appreciable violence. Table 2 lists 42 other ignitions in which no fatalities resulted and no violence was noted but which caused burns or other injuries to 66 men; it is certain that many other such instances passed without being reported, hence this list must be regarded merely as an exhibit of potential disasters which were escaped by fortunate chance, as protective measures were so few, that it is questionable if they aided in limiting the explosions.

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TABLE 2. - Nonfatal ignitions of gas or dust, 1877 - 1932.

Year	County	Circumstances	Source of ignition	Men injured
1877	Clay.	Feeder from roof fissure.	Open light.	2 miners.
1880	Muhlenberg.	Unventilated.	do.	Owner.
1881	Clay.	Feeder from roof fissure.	do.	1 miner.
1887	Hopkins	Insufficient ventilation.	do.	2 miners.
1893	Union	Unventilated section.	do.	Driller.
1894	Lee.	Powder and dust.	Overcharged shot.	3 miners.
1896	Whitley.	Powder smoke, dust, and gas.	Black powder shot on solid.	1 miner.
1898	Bell.	Feeders and insufficient ventilation.	Open light.	Superintendent.
1899	Muhlenberg.	Insufficient ventilation and inspection.	do.	Bank boss.
1901	Hopkins.	Dust and black powder.	Blown-out shot.	3 miners.
1901	do.	Poor ventilation.	Open light.	2 miners.
1903	Union.	Insufficient ventilation and inspection.	do.	do.
1904	Hopkins.	Old unventilated room.	do.	1 miner.
1904	Muhlenberg.	Gas, dust, powder smoke.	Blown-out shot.	2 miners.
1904	Union.	Poor ventilation.	Open light.	3 miners.
1904	Muhlenberg	Unventilated fire area.	do.	do.
1905	Hopkins.	Poor ventilation.	do.	1 miner.
1906	do.	Abandoned unventilated room.	do.	do.
1906	Knox.	Powder smoke, gas, and dust.	Blasting.	3 miners.
1906	Muhlenberg.	do.	do.	1 miner.
1907	Carter.	Poor ventilation and black blasting powder.	Blown-out shot.	3 miners.
1907	Knox.	Powder smoke, gas, and dust.	Blasting.	4 miners.
1907	Whitley.	Dust and powder.	"Windy" shot.	2 miners.
1909	Hopkins.	Unventilated idle heading.	Open light.	1 driver.
1909	Muhlenberg.	Shot 11 holes near one another, smoke and dust.	Blasting.	1 shot firer.
1910	do.	Feeder and poor ventilation.	Open light.	1 miner.
1911	Whitley.	Insufficient ventilation, no inspection.	do.	do.
1913	McCreary.	Overfall, brushed out.	do.	Superintendent.

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TABLE 2. - Nonfatal ignitions of gas or dust, 1877 - 1932 (Continued)

Year	County	Circumstances	Source of ignition	Men injured.
1913	McCreary.	Gas in room, brushed out.	Open light.	1 miner.
1919	do.	Entry head, insufficient ventilation.	do.	2 miners.
1920	do.	Insufficient ventilation, entry head.	do.	1 miner.
1920	do.	Insufficient ventilation and inspection of entry.	do.	do.
1921	do.	do.	do.	do.
1922	Bell.	Insufficient ventilation, no inspection.	do.	2 miners.
1924	McCreary.	Insufficient ventilation.	do.	1 tool nipper.
1924	Floyd	do.	do.	1 miner.
1926	McCreary.	Insufficient ventilation and inspection.	do.	2 shot firers.
1927	do.	Idle room, gas known, nor marked.	do.	1 miner.
1928	do.	Insufficient ventilation and inspection.	do.	do.
1928	Martin.	Insufficient ventilation, nongassy.	do.	do.
1928	McCreary.	Insufficient ventilation and inspection.	do.	1 machine man.
1929	do.	Insufficient ventilation and inspection of entry.	do.	do.

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TABLE 3. - Explosion fatality rates and percentage of total for different periods

Period, years	Fatality per million		Percent of total no. killed	
	Tons	Man-hours (inside)	Kentucky	United States
1884-1890 (7 years)	0.43	0.10	11.8	9.0 (est.)
1891-1900 (10 years)	.19	.05	6.5	15.9
1901-1910 (10 years)	.90	.31	23.5	30.0
1911-1920 (10 years)	.35	.17	10.9	12.4
1921-1925 (5 years)	.32	.22	9.7	14.8
1926-1930 (5 years)	.21	.14	7.0	12.5
1931	.08	.06	2.7	6.0
1932	.65	.57	22.8	14.3
Total, 1884-1932	- -	- -	11.0	14.0

FATALITIES[4]

Available records, as listed in table 1, indicate that in the 49-1/2 years from January 1, 1884, to June 30, 1933, 344 fatalities occurred in Kentucky coal mines as a result of 73 explosions of gas and dust, an average of 4.7 fatalities for each explosion. In 12 explosions none was killed. The greatest number of deaths in a single explosion was 62, and the next highest number was 34. Only 6 explosions claimed more than 10 victims. The records show 123 men injured more or less seriously in these 73 explosions. It is notable that few escaped such disasters with injury and that in the last 15 explosions only 1 injured man survived.

Table 3 presents the gas and dust fatality rates per million tons mined and per million man-hours of underground exposure. These rates parallel closely those of some older coal-producing States. The high tonnage rating up to 1910 is usual, reflecting the low tonnage per man-day of that period. The drop from this point may be attributed to two influences--greater tonnage per man and safer practices introduced to reduce explosion hazards. The rating on the man-hour basis is the more significant from the viewpoint of safety to the men. The rates of 0.17 fatality per million man-hours from 1911 to 1920 and 0.22 from 1921 to 1925 are due to a long series of large and small explosions coincident with an increase in production from 14 to 60 million tons, with an increase in man-hours from about 35 to 80 millions.

4 The number of explosions and men killed differ from yearly totals given by the Bureau of Mines and the State due to the inclusion of fatalities segregated by them under other headings and some in mines not under State control.

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The average rates for the 5-year period from 1926 to 1930 were 0.21 per million tons and 0.14 per million man-hours. The corresponding rate per million man-hours for the United States was 0.31. In 1931 only 3 fatalities occurred from this source in Kentucky, giving fatality rates of 0.08 and 0.06 per million tons and man-hours, respectively. These rates jumped to 0.65 and 0.57, respectively, in 1932, when 28 men were killed in 1 explosion. In 1932 fatality rates for the country as a whole were 0.47 per million tons and 0.25 per million man-hours.

Gas-and-dust explosion fatalities in Kentucky averaged 10 percent of the total number killed in coal mines of the State over the entire period, 1884 to June 30, 1933, inclusive. In comparison, those killed in explosions in coal mines of the entire United States for this period were about 14 percent of the total; it is possible that this ratio indicates approximately the relative hazard from this source for Kentucky coal mines compared with coal mines of the United States as a whole.

CAUSES OF EXPLOSIONS

Three general causes are given for explosions in Kentucky. The majority, 42, were caused by so-called "windy" or blown-out shots, 27 by open lights or flames, and 2 by electric arcs. In 2 others no details are available, but in all probability blasting was the cause.

TABLE 4. - Causes of Explosions in Kentucky coal mines, January 1, 1884, to June 30, 1933.

Causes	Explosions	Percent
Blasting	42	57
Open lights or flames	27	37
Electric arcs	2	3
Not given	2	3
Total	73	100

Blasting. - In the 49-1.2 year period 57 percent of the explosions listed in table 1 were caused by blasting. From 1884 to 1917, inclusive, there were 28, or 78 percent of a total of 36 explosions from blown-out or "windy" shots; from 1918 to 1927, inclusive, there were 11 explosions from this cause, or 38 percent of the 29 explosions which occurred during this period. Three, or 40 percent of the 8 explosions occurring from January 1, 1928, to June 30, 1933, were from blasting.

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TABLE 3. - Summary of conditions attending explosions caused by blasting in Kentucky coal mines

Causes	Explosions
Solid shooting, blown-out or "windy" shot, coal-dust stemming, igniting accumulated explosives, smoke and dust	7
Solid shooting, blown-out or "windy" shot, coal-dust stemming, igniting dust	21
Solid shooting, blown-out or "windy" shot, coal-dust stemming, igniting gas and dust	6
Solid shooting, blown-out or "windy" shot, coal dust stemming, igniting kegs of black blasting powder and dust	6
Dynamite on large rock, dust explosion	1
Keg of black blasting powder ignited by open light	1
Total	42

Except for the case where dynamite was placed on a large rock to break it, all explosions by blasting were caused by shooting coal off the solid or using black powder in keg or pellet form. In 21 cases dust was raised into a cloud and ignited by black blasting-powder shots. In 7 other cases accumulated explosives smoke and dust were blamed; in 6 more cases concentrations of gas and dust were ignited; and in the other 6 cases kegs of black blasting powder stored in the workings were ignited and helped to propagate dust explosions. Coal-dust stemming helped to ignite the dust cloud in numerous instances despite admonitions of the assistant inspectors, repeated year after year, to use clay or other incombustible material. The greatest hazard lies in the practice of shooting from the solid with little or no supervision. Had it not been for the introduction in certain mines of regulations requiring shooting to be done by shot-firers after the men on the regular shift were out of the mine the loss of life undoubtedly would have been much greater. Lack of adequate ventilation, which allowed dust, gas, and smoke to hang in clouds, was a contributing factor in numerous instances. The dominant cause was the use of black blasting powder, first in keg form and more lately in the pellet or stick form. Two disastrous dust explosions occurred in mines in which the coal was cut by machine and in which some shooting from the solid was also allowed; and in 40 of the 42 explosions caused by blasting, solid shooting was in effect.

Open lights.- Twenty-seven (37 percent of the 73 explosions listed in table 1) were caused by open lights, including all types of open flames. Except in 2 cases, open-flame miners' lamps were the source of the ignitions;

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ignition in one mine was charged to the boiler fires or other open flame on the surface and in the other to smoking at the face.

From 1884 to 1917, inclusive, 8 (22 percent) of the 36 explosions listed were caused by open lights or flames. In the next 10 years, from 1918 to 1927, inclusive, 14 (50 percent) of the explosions fell in this class. From 1928 to June 30, 1933, 50 percent of the explosions were initiated by open flames.

TABLE 6. - Summary of conditions attending explosions caused by open lights in Kentucky

Causes	Explosions
Carrying open light into unventilated, uninspected, working place	14
Carrying open light into marked-out place	5
Brushing out gas in presence of open light	2
Use of open light while inspecting for gas	4
Smoking at unventilated face	1
Outburst of gas reached open flame at surface	1
Total	27

The use of open lights in mines which in the majority of cases were known to liberate gas was also concomitant with other notable lapses from safe practices in all but the last instance. These unsafe practices frequently violated warnings and instructions issued by the State inspectors. Neglect or refusal to conform with recognized standards is evidence of lack of supervision or of inefficient supervision.

Electric arcs.- The 2 explosions attributed to electric arcs occurred in the same year, 1927. In one explosion power had been cut off the mine, and the fan had been idle overnight. Arcing from a blower-fan motor inside the mine ignited accumulated gas when the main switch was put in the next morning. The second explosion occurred when gas liberated by blasting passed over an open-type mining machine operating on the return airway. Proper inspection for gas was not made in either case.

TYPES OF EXPLOSIONS

The classification of mines as gassy or nongassy as given below and in table 1 is based on the evidence as to actual presence of gas in appreciable amounts before the explosion. The Kentucky mining law provides for the

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grouping of mines under these headings, and mines are so classified by the State Department, but since the division involves a vague rating as "dusty" and does not conform to U. S. Bureau of Mines recommended standards, the classification as expressed in Mine Safety Board Decision 3 has been followed in rating the mine as gassy or nongassy in the following tabulation:

Types of explosions

Known condition of mine	Explosions of			Total
	Gas	Dust	Gas and dust	
Nongassy	1	28	0	29
Gassy	22	11	11	44
Explosions	23	39	11	73
Fatalities	41	137	166	344

The 73 explosions listed in table 1 are summarized in the above tabulation to show the number of gas, dust, or gas-and-dust explosions in nongassy and gassy mines and the number of fatalities resulting from explosions in each type of mine. Several ignitions occurred in mines not previously known to give off explosive gas; in fact, most of those in early years listed in table 2 were in this class. Several explosions were initiated by gas in mines which were not rated as gassy by the operators or the State. The U. S. Bureau of Mines considers all coal mines potentially gassy; nevertheless, it must be recognized that numerous mines in Kentucky are essentially nongassy, particularly those in the high ridge districts.

TABLE 7. - Fatalities and number of men possibly involved in Kentucky explosions

Mine rating	Explosions	Gas			Dust			Gas and dust		
		Cases	Fatalities	Men in area	Cases	Fatalities	Men in area	Cases	Fatalities	Men in area
Nongassy	Local.	1	4	10	7	4	85	-	-	-
Do.	Violent.	-	-	-	21	96	164	-	-	-
Gassy	Local.	19	24	1,587	4	5	121	5	32	360
Do.	Violent.	3	13	13	7	32	37	6	134	636

The above table indicates the large number of fatalities due to gas-and-dust explosions in gassy mines and the smaller number of fatalities due to dust explosions in which gas was not involved. Explosions of gas and dust were in numerous cases initiated by ignition of gas accumulations during the working shift when full crews were in the mines; for this reason the loss of life was heavy when the explosions were propagated by dust throughout a considerable part of the workings. Dust explosions that were more or less violent, and the majority were of this nature, occurred more often when only

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shot firers or a few other employees were in the mine; in these cases few escaped. Had it not been for regulations, imposed in certain mines, prohibiting shooting off the solid during the working shift, the loss of life would probably have been 500 or 1,000 instead of 128 in these few cases. However, it is unthinkable that such disregard of human life would have been countenanced. The explosions involving gas alone were nearly all localized, since where any amount of violence was developed dust was ignited, bringing the occurrence under the gas and dust division.

PREVENTION OF EXPLOSIONS IN KENTUCKY COAL MINES

It is now fairly well-established that all mine explosions are preventable. The necessary knowledge of the causation of mine explosions and means of absolute prevention to insure protection from them have been available for at least 15 years. Recommendations were made in reports on the various explosions by the State Department of Mines and by the United States Bureau of Mines representatives to prevent recurrence of similar explosions; these recommendations represented the best accepted safety practices at the time they were made. The number of times such recommendations were given is shown in table 8.

Table 8. - Recommendations for preventing Kentucky explosions made at the time of the explosions

Recommendations	Times made
Cutting or mining of coal instead of solid shooting	38
Adoption of a proper system of ventilation or improvement of ventilation	25
Use of safer blasting practices (abandonment of the use of overcharged or straight holes, coal-dust stemming, etc.)	24
Control of dust (watering, dust removal, rock-dusting, water on cutter bar)	22
Installation of permissible (closed) lights	22
Provision of effective inspection	18
Adoption of permissible explosives and blasting methods	18
Provision of adequate supervision	11
Adoption of safer methods of storing and handling black blasting powder	2
Ventilation of mine or parts of it before entering	2
Sealing of unventilated areas	1
Prohibition of smoking	1
Use of permissible electric equipment only	1
Provision of boreholes to release gas from sealed or confined workings	1

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Mined coal v. solid shooting.- The following tabulation shows the slow progress from solid shooting to machine mining in many of the mines; little real pick mining was done at any time, and considerable solid shooting is practiced at present.

TABLE 9. - Proportion of machine-mined coal to total production in Kentucky, percent

Year	West district	Southeast district	Northeast district	State
1909	80	27	47	58
1910	74	36	66	62
1911	79	32	74	63
1920	-	-	-	78
1924	-	-	-	87
1928	-	-	-	92
1931	-	-	-	91

The recommendation to cut the coal was made in 38 of the 73 reports prepared in connection with explosions in Kentucky coal mines.

Explosions due primarily to solid shooting were numerous and of more or less regular occurrence until about 1923; several have occurred since that date--2 in 1923, 1 in 1924, 2 in 1925, 1 in 1926, 1 in 1929, and 1 in 1932. All explosions were in mines in which the coal was supposed to be cut but in which more or less solid shooting, supposedly as an exception, was permitted. The tendency is toward total elimination of this practice, and the exceptions should be reduced to zero.

Ventilation.- In 1884, when the first State mine inspector assumed office, most of the mines depended on natural ventilation or on small fire baskets to produce limited circulation. For years he urged better means of ventilation. Furnaces were next installed, and they were numerous as late as 1912. A fan installation was described in 1891, and from that time on fans were advocated to replace furnaces. The virtually nongassy condition of many mines with outcrops on high ridges and numerous openings to the surface has had the effect of minimizing the importance of ventilation and inspection over much of the State.

The recommendation to improve ventilation was made in 25 instances in the reports prepared after explosions; many of these were cases in which lack of adequate circulation of the air allowed smoke and fumes, as well as very finely divided dust, to collect to such an extent after heavy blasting that ignition from a "windy" or blown-out shot occurred. Several such ignitions are also recorded in table 2, giving data on some explosions in which no fatalities occurred; the recommendation to improve ventilation was made in nearly every instance where gas was involved, and in some in which dust was the active factor.

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An adequately controlled ventilating system providing for a sufficient quantity of fresh air to be conducted to and to render harmless all gases at every working face is of primary importance in every mine from an explosion and health standpoint.

Safer blasting.- Safer blasting includes recommendations dealing with proper drilling and placing of holes, limiting the amount of black blasting powder put in any hole and the number of holes shot at a time, using clay stemming in place of coal or other combustible dust, and shooting at prescribed times. One of several of these hazards contributed to an explosion in 34 instances. These occurred in the period before permissible explosives were generally known and available; after that time equivalent recommendations are grouped under "permissible blasting".

Permissible explosives and blasting.- The recommendation for use of permissible explosives and recognized safe blasting methods was made in 18 instances; in all probability at least 18 explosions in Kentucky would have been avoided through the use of available safe, effective types of explosives. The following tabulation shows the relative percentages of the three chief types of explosives used in the coal mines of Kentucky at various periods:

TABLE 10. - Explosives used in Kentucky coal mines

Year	Black blasting powder	Dynamite	Permissible explosives
1911	Nearly all.	-	Some in northeast field and small amount in western field.
1924	83	?	17
1925	82	1	17
1926	82	2	16
1927	76	1	23
1931	68	3	29

In this tabulation all black blasting powder, whether in granular, pellet, or stick form, is grouped together. Until recent years nearly all black blasting powder was in granular form but has been largely replaced by pellet and stick varieties. From an explosion standpoint the risks are essentially the same. Dynamite is used virtually entirely in shooting top rock; in this it constitutes a grave hazard and its use is entirely unnecessary, as types of permissible explosives are available which do this work effectively and safely.

At the beginning of 1933 the State Mining Department renewed its efforts to induce operators to use permissible explosives, with a gratifying response from several progressive companies; by all means the use should be universal in Kentucky coal mines.

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Dynamite has been charged with initiating only one explosion, in which an open charge was exploded on a large piece of rock. The hazards of black blasting powder and dynamite are generally well-known; and, although the effectiveness and safety of permissible explosives are established and can be demonstrated, nonpermissible explosives are widely and persistently used, chiefly on account of an inherent reluctance to change from established practices.

Dust control.- In 1932 there were 18 explosions in bituminous mines in the United States. In four of these mines rock-dust localized the explosion and saved 100 to 300 lives. In two other partly protected mines the explosion spread to untreated workings and claimed the lives of 15 or 20 men therein.

Over the period of 49-1/2 years, January 1, 1884 to June 30, 1933, in 73 Kentucky explosions dust control was advised as a major preventive measure 22 times, indicating that in at least that number the initial explosion very probably was propagated by dust, with resulting destruction and loss of life. In almost every other instance the explosion might have been propagated by coal dust so that some means of protection against this hazard should have been provided. The reasons for nonpropagation of flame were chiefly weakness of the starting force and rapid release of pressure into nearby openings although dampness and incombustible material naturally present in the dust aided in at least eight instances.

Rock-dust stopped explosions in two mines. One explosion was confined to a non-rock-dusted entry, in which 17 men were killed; a total of 180 men were employed underground, and it is believed that many if not all of 103 lives were saved in this mine through the effectiveness of rock-dust. Another explosion in the same district was arrested by rock-dust; 15 men were killed, and 30 men escaped, undoubtedly due to the efficacy of the rock-dust. Coal-dust explosibility control through application of rock-dust was responsible in these two instances for saving possibly 193 lives. Natural rock-dusting--that is, dust high in incombustible material--was credited with stopping another explosion in which 3 lives were lost and 6 men escaped.

Rock-dust, to be effective, must be so maintained that the incombustible content of the dust exceeds the minimum necessary to prevent propagation of an explosion. The fine dust of the No. 9 or Keokee bed requires at least 76 percent incombustible matter to make it nonexplosive. Failure to extend and maintain rock-dusting over a period of approximately one year resulted in a relatively large number of fatalities in an explosion in one Kentucky mine; an explosion resulted in the loss of 23 lives in a mine in which 37 men were underground, and although the main entry had been rock-dusted about a year before the explosion the active workings had not been rock-dusted, and the explosion extended throughout the active workings.

In 1895 Chief Mine Inspector C. J. Norwood included in his annual report a review and explanation of studies that proved the explosive properties of coal dust. For years the only known methods of reducing this hazard were removal of large accumulations of dust and sprinkling, combined with shooting after the shift was out of the mine.

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The use of rock-dust was actively advised in the State by engineers of the United States Bureau of Mines about 1920, and certain companies in the western field experimented and adopted its use at that time. Experience has shown the need of such protection in all parts of the State, and recently marked interest has been taken in the explosion-prevention method. Several mines have been rock-dusted, and operators of other mines are giving the matter serious consideration.

Permissible (closed) lights.- Twenty-two mine explosions in Kentucky were caused by the use of open-flame miners' lights in gassy mines after practical electric cap lamps had been in use in some States for several years and their use generally advocated in all coal mines and especially in gassy mines. Fifteen ignitions listed in table 2 were caused by open lights in gassy mines.. In the years before practical electric cap lamps were developed the use of any one of several makes of flame safety lamps instead of open flame lights when unventilated and uninspected workings were entered would have prevented several disastrous explosions causing nonfatal injuries.

Approximately 137 electric cap lamps were in use in the State of Kentucky in 1918 and about 1,966 in 1928. The number in use in July, 1933, is reliably estimated to be about 5,300. In 1928 there were about 53,600 men in the mines, and there are about 40,000 in 1933.

Present-day electric cap lamps of approved types are more economical, more efficient, and more safe than open-flame miners' lamps; the Bureau of Mines recommends the exclusive use of closed lights in all coal mines, as experience has demonstrated not only in Kentucky but also in virtually every other coal-producing State in the Union that open-flame lights are hazardous.

Inspection.- Eighteen of the 73 explosions were charged to failure, through lack or neglect of inspection, to find and remove gas accumulations before men were permitted to enter, or in other instances to test for gas before shooting or putting power on open-type equipment.

Not only should fireboss inspections be made for gas and close attention be given to the ventilating system to prevent gas from accumulating, but an inspector should also regularly survey dust-control methods, such as watering, cleaning dust from roadways, and rock-dusting; should keep a close check on electrical equipment to see that arcing and sparking are reduced to a minimum, especially at or near working faces; and should see that all open-flame lamps and smoking are barred from all coal mines whether gassy or nongassy.

Supervision.- Direct responsibility for explosions was charged to lack of adequate supervision in 11 reports on these disasters. In a majority of all the cases inadequate supervision was held to be a factor, and recommendations were made that this function be more effectively exercised in connection with various phases of operation.

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In 1914 a new mining law in Kentucky provided that the mine foreman should devote the whole of his time to his duties, defined them, including the noting of all dangers and the taking of proper precautions promptly, and made him responsible. The responsibility of those in charge for the acts of employees cannot be evaded, hence supervision should be intelligent, rigid, and continuous.

Miscellaneous recommendations.- Six other recommendations were made as corollaries to the preceding main recommendations; these included blasting, ventilation, sealing of abandoned or unventilated areas, smoking, use of permissible electrical equipment, and provision of boreholes to release gas in sealed workings.

TABLE 11. - Number of explosions and fatalities from them in Kentucky mines, January 1, 1884 - June 30, 1933

Years	Explosions	Fatalities	Average fatalities per explosion
1884-1890[1]	2	6	3.0
1891-1900	4	7	1.75
1901-1910	20	83	4.15
1911-1920	16	84	5.25
1921-1930	28	135	4.82
1931-June 30, 1933[2]	3	29	9.67
Total	73	244	3.34

1/ 7 years only.
2/ 2-1/2 years only.

The explosions and fatalities from explosions have been arranged by periods (and chiefly by decades) from January 1, 1884, to June 30, 1933. It may be noted that the number of explosions and fatalities increased with the development of the industry in the State to about 1930. Table 1 shows that although there had been two or more fatal explosions in Kentucky coal mines annually for many years up to 1928, there has been but one annually from 1929 to 1933, inclusive. The severity is apparently on the increase, although the 2-1/2-year period, January 1, 1931 to June 30, 1933, is too short to use in making generalized comparisons.

RECOMMENDATIONS

The United States Bureau of Mines, through its Mine Safety Board, issues "decisions" on safety methods and practices. Such decisions as relate to explosion-prevention methods are as follows:

Decision 1.- The Bureau of Mines recommends:

1. In all coal mines the portable lamps for illumination be permissible, portable, electric mine lamps; and also

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2. In places where fire damp or black damp is liable to be encountered, a permissible magnetically-locked, flame safety lamp for gas detection, or equivalent permissible device, be supplied to at least one experienced employee in each such place; and

3. Any employee before being supplied with a permissible flame safety lamp be examined by a competent official of the mine to assure the man's ability to detect gas; and

4. All coal mines whether classed as nongassy or gassy in any part, be supplied with magnetically locked, permissible, flame safety lamps, properly maintained and in sufficient number for all inspection purposes.

Decision 2.- In the interests of safety the Bureau of Mines recommends that for blasting in coal mines, permissible explosives, fired electrically, be exclusively used; and that as an aid to blasting, all coal which is feasible to cut, should be cut or sheared.

Decision 4.- In the interest of safety, the Bureau of Mines, Department of Commerce, recommends that auxiliary fans or blowers should not be used in coal mines as a substitute for methods of regular and continuous coursing of the air to every face of the mine.

Decision 5.- To prevent the propagation of mine explosion, the Bureau of Mines, Department of Commerce, recommends rock-dusting all coal mines, except anthracite mines, in every part, whether in damp or dry condition. It also recommends that rock-dust barriers be used to sectionalize the mine as additional defense; but these should not be regarded as a substitute for generalized rock-dusting.

Decision 6.- In the interest of safety, the Bureau of Mines, Department of Commerce, recommends that in coal mines all entries, rooms, panels, or sections that cannot be kept well ventilated throughout or cannot be inspected regularly and thoroughly, or that are not being used for coursing the air, travel, haulage, or the extraction of coal, be sealed by strong fireproof stoppings.

Decision 7.- In the interest of safety, the Bureau of Mines, Department of Commerce, recommends:

1. That the main intake and main return air currents in mines be in separate shafts, slopes, or drifts.

2. That the main intake shaft lining be of fireproof construction, and there be a minimum amount of inflammable material in or adjacent to the shaft.

Decision 9.- The Bureau of Mines, Department of Commerce, recommends in coal-mine ventilation practice the following specifications as to unit quantity and quality of air:

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1. The quantity in cubic feet of pure intake air flowing per minute in any ventilating split shall be at least equal to 100 times the number of men in that split.

2. The quantity of air entering each unsealed place shall be at least 200 cubic feet per minute and as much more as may be necessary to properly dilute and carry away inflammable or harmful gases which may be present.

3. The air shall be made to circulate continuously to the face in every unsealed place into which an appreciable amount of methane enters.

4. The air in any unsealed place shall be considered unfit for men if it shall be found to contain less than 19 percent oxygen (dry basis), more than 1 percent carbon dioxide, or a harmful amount of poisonous gas.

5. If the air in any unsealed place, when sampled or tested in any part of that place not nearer than 4 feet from the face and 10 inches from the roof, shall be found to contain:

(a) More than 1-1/2 percent of inflammable gas, the place shall be considered to be in hazardous condition and require improved ventilation, and

(b) If more than 2-1/2 percent of inflammable gas is found, the place shall be considered dangerous, and only men who have been officially designated to improve the ventilation and are properly protected shall remain in or enter said place.

6. If the air in the split which ventilates any group of workings contains more than 1-1/2 percent of inflammable gas, these workings shall be considered to be in a dangerous condition and only men who have been officially designated to improve the ventilation and are properly protected shall remain in or enter said workings.

Decision 11.- In the interest of safety, the Bureau of Mines, Department of Commerce, recommends that in coal mines, haulage and (or) hoisting be kept in intake air as far as possible.

Decision 12.- The Bureau of Mines, Department of Commerce, extending Mine Safety Decision No. 2, recommends that for blasting either coal or rock in coal mines, permissible explosives or equivalent permissible device be used exclusively, and in addition recommends that in blasting

1. Each charge shall be in a hole properly drilled and stemmed with incombustible material.

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2. Each shot shall be fired separately by a permissible single-shot blasting unit, using an electric detonator or igniting equivalent of a kind specified by the bureau for the particular permissible explosive or permissible blasting device.

3. Before and following each shot in gassy and slightly gassy coal mines, examination for gas shall be made with a permissible flame safety lamp or permissible equivalent and

4. If more than 1-1/2 percent of inflammable gas is found, in the quantity and by the method specified in Mine Safety Decision 9, the place shall be considered to be in a hazardous condition and before another shot is fired the gas shall be reduced by ventilation below the percentage and quantity specified in Decision 9.

5. Each shot employing explosives shall be prepared and fired by or under the immediate supervision of a man having a state certificate as a mine examiner, fire boss, or foreman; and whenever conditions permit all other men than those authorized to prepared and fire shots shall be out of the mine when shot firing with explosives is being done.

Decision 13.- The Bureau of Mines, Department of Commerce, recommends that when electricity is used in coal mines rated as gassy, or whenever in any mine the atmosphere may become gassy:

1. Electrical equipment shall be permissible.

2. Nonpermicsible electrical equipment shall be used only in pure intake air.

3. Electrical power shall be cut off whenever the air in the workings is in a dangerous condition, due to inflammable gas.

Decision 15.- In the interest of safety in coal mining, the Bureau of Mines, Department of Commerce, recommends that, to lessen the coal-dust explosion hazard:

1. Machine coal cuttings be wet as the cutting is being done.

2. The coal face, and the working place 40 feet therefrom, shall be kept free of coal-dust by the use of water.

3. The top of loaded cars in the working place shall be wet.

Decision 16.- In the interest of safety in coal mining, the Bureau of Mines, Department of Commerce, recommends that:

1. Machine cuttings be removed from the cut.

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Open-flame lamps have caused 37 percent of Kentucky coal-mine explosions, and realization of the hazards of this type of lamp by the mine owners is indicated by the fact that 2.3 times as many permissible electric cap lamps were in use early in 1933 as in 1928. Unquestionably open lights should be superseded in Kentucky coal mines by the far safer and more efficient closed lights now readily available.

The 73 explosions in Kentucky mines listed in table 1 represent a total daily average production of 41,195 tons of coal. The total average underground employment represented is 7,988, and of this number 3,127 men were reported to have been in the mine at the time of the explosions. The total number killed was 344 or approximately 11 percent of the men exposed to the explosions; 123, or about 4 percent of those underground, were injured. In other words, nearly 15 percent of the men underground were affected by the explosions. The number (159) that escaped from the mine or the area affected by the explosion represents slightly more than 5 percent of the total number underground. The relatively high mortality rate (55 percent) of the 626 persons in the affected area, consisting of 344 killed, 123 injured, and only 159 uninjured, emphasizes the necessity for adopting dust-control methods. Only about 25 percent of those in the explosion areas escaped; if all mines listed in table 1 had been adequately rock-dusted the number of fatalities in all probability would have been very remarkably reduced.

During the past 5 years an earnest effort has been made to eliminate coal-mine explosions in Kentucky. If the recommendations of the State Department of Mines and the United States Bureau of Mines are adopted generally, especially those for substituting permissible explosives and blasting supplies for nonpermissible explosives and fuse, permissible lamps for open-flame lamps, and improved methods of ventilation, the groundwork already laid undoubtedly will form a permanent foundation for preventing coal-mine explosions, with their attendant unnecessary loss of both property and human life.

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